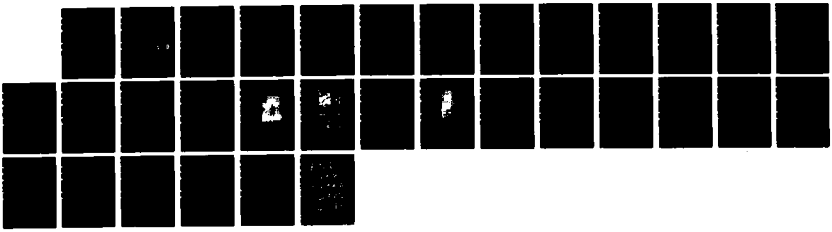
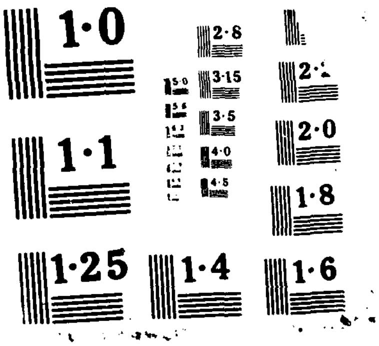
AD-A192 844 A PLASMA ULTRAVIOLET SOURCE FOR SHORT WAVELENGTH LASERS 1/1
(U) HAMPTON UNIV VA DEPT OF PHYSICS K S HAN 15 APR 88
ARO-23496 5-PH-H DAAL03-86-G-0003

UNCLASSIFIED F/G 9/3 NL




1·0
2·8
3·15
3·5
4·0
4·5
2·0
1·1
1·8
1·25
1·4
1·6

DTIC FILE COPY

AD-A192 844

(2)

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARO 23496.5-PH-H	2. GOVT ACCESSION NO. N/A	3. RECIPIENT'S CATALOG NUMBER N/A
4. TITLE (and Subtitle) A Plasma Ultraviolet Source for Short Wavelength Lasers		5. TYPE OF REPORT & PERIOD COVERED Final Report (1/15/86-2/29/88)
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) K. S. Han		8. CONTRACT OR GRANT NUMBER(s) DAAL03-86-G-0003
9. PERFORMING ORGANIZATION NAME AND ADDRESS Hampton University		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N/A
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Research Office Post Office Box 12211 Research Triangle Park, NC 27709		12. REPORT DATE 4-15-88
		13. NUMBER OF PAGES 29
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DTIC ELECTE MAY 1 1 1988 S D H

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

NA

18. SUPPLEMENTARY NOTES

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Plasma uv source, Dense Plasma Focus, Hard-Core Flashlamp, Blue-Green Laser LD490 dye

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A dense plasma focus (DPF) device was evaluated for the feasibility of blue-green and near uv laser pumping. As the result of optimizing the operating conditions of DPF and laser system, the maximum untuned laser output exceeded 4.0mJ corresponding to the energy density 8.3J/liter which is much higher than the typical flashlamp dye laser. The spectral irradiance of DPF at the absorptio

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT CONTINUED

bands for LD390 and LD490 were 5.5W/cm^2-nm, 0.3W/cm^{2}nm, respectively. Due to the lower pump powerof DPF at 355nm than the threshold of LD390, the laser pumping of LD390 dye was not achieved.

A hard-core flashlamp (HCF) which has a coaxial geometry and array of inverse pinches was also evaluated for blue-green and near uv laser excitation. The short pulse (>0.5us) surface discharges were produced across the core insulator of alumina. The spectral irradiance of the HCF depends on argon fill gas pressure and the core insulating material. The maximum radiative output of the HCF lie in the region of 340-400nm (absorption band of LD490). A LD490 dye laser pumped by a HCF prototype device had an output of 0.9mJ with a pulse of 0.5 μs ~~(FWHM)~~

A Plasma Ultraviolet Source for Short Wavelength Lasers

Final Report

April 15, l988

U. S. Army Research Office

DAAL03-86-G-0003

Hampton University

Dept of Physics

Hampton, VA 23668

Approved For Public Release

Distribution unlimited

88 5 10 165

A PLASMA ULTRAVIOLET SOURCE FOR SHORT WAVELENGTH LASERS

CONTENTS

Abstract

A dense plasma focus (DPF) device was evaluated for the feasibility of blue-green and near uv laser pumping. As the result of optimizing the operating conditions of DPF and laser system, the maximum untuned laser output exceeded 4.0 mJ corresponding to the energy density 8.3J/liter which is much higher than the typical flashlamp dye laser. The spectral irradiance of DPF at the absorption bands for LD390 and LD490 were 5.5 W/cm^2-nm, and 0.3 W/cm^{2}nm, respectively. Due to the lower pump power of DPF at 355nm than the threshold of LD390, the laser pumping of LD390 dye was not achieved.

A hard-core flashlamp (HCF) which has a coaxial geometry and array of inverse pinches was also evaluated for blue-green and near uv laser excitation. The short pulse (<0.5μs) surface discharges were produced across the core insulator of teflon and alumina. The spectral irradiance of the HCF depends on argon fill gas pressure and the core insulating material. The maximum radiative output of the HCF lie in the region of 340 - 400nm (absorption band of LD490). A LD490 dye laser pumped by a HCF prototype device had an output of 0.9mJ with a pulse of 0.5μs (FWHM).

I. Introduction

Importance of tunable ultraviolet lasers for photochemical research and applications have led to several methods of producing high power uv lasers below $\lambda = 350nm$. Frequency doubled or tripled high power uv lasers such as ion, ruby, Nd^{+3}, and visible dye lasers as well as short wavelength excimer lasers are complex and expensive systems themselves. Consequently, their applications are limited. Therefore, availability of inexpensive flashlamp-pumped high power dye lasers is desirable for the uv range. The flashlamp pumped uv dye lasers are currently available only wavelength above 330nm and their output energy (< 1J) are limited. This is mainly due to the lack of uv emission from the flashlamp used as the pump source. Efforts to improve the flashlamp-emission efficiency in the uv range have thus far met with limited successes indicating that the radically different and new light source are required. Such-reptitive sources as exploding wires or foils which have been studied as intense uv sources for an iodine laser are extreme examples (Ref. 1). Other examples are use of dense plasma sources as investigated in the USSR laboratories for high power laser pumping (Ref. 2, 3, 4). They produced dense plasma by high current discharges but in a different regime than that of the thermonuclear fusion device (or plasma devices). They report the efficiency of over 70% in terms of the total radiated energy and over I kJ of a gas laser output production in 0.251 to 1.04 μm.

Recently in the USA, dense plasma focuses produced in hypocycloidal pinch array have been successfully employed for various laser pumping (Ref. 5), especially, dye laser pumping at our laboratory (Ref. 6) and at University of Illinois (Ref. 7). There also has been preliminary attempted using a coaxial-gun type plasma focus device for dye laser pumping (Ref. 8). However, the optical coupling and operational conditions of the plasma focus-laser system have not been optimized in this preliminary test and further investigation is necessary to evaluate its potential as a high-power uv laser system.

In order to evaluate the feasibility of blue-green and near uv laser pumping with the dense plasma focus (DPF) device, the emission spectra of the DPF was analyzed in terms of current sheet

velocity and spectral irradiance at the dye cuvette with different type fill gas and fill gas pressure. Furthermore, laser output characteristics of blue-green and near uv lasers with the DPF pumping light were studied. Details are discussed in chapter II.

A hard-core flashlamp (HCF) which has a coaxial geometry and an array of inverse pinches was also evaluated for blue-green and near uv laser excitation. Details are discussed in chapter III.

II. A dense plasma focus for blue-green and near uv dye laser

A high power blue-green laser has been pumped with the dense plasma focus device similar to Ref. 9 and 10. As shown in figure 1, new features include magnetic stabilization of the plasma and optical coupling with an elliptical cylinder focussing mirror along Z axis and the laser gain medium at another foci. The device was operated at 18kV (8.1kJ) with fill gas of 0.5Torr (90% deuterium and 10% argon). The measured maximum output energy of blue-green laser approximately 4.0 mJ and output energy density was 8.3J/liter which is much higher than the typical flashlamp pumped dye laser. In order to determine the optimum conditions of pumping blue-green and near uv laser, the emission characteristics (200-400nm), the current sheet dynamics, the pressure, and input energy dependence of the laser laser output were measured. Figure 2 shows a block diagram of experimental set-up. Figure 3 shows average speed of current sheet viewed from the side of electrodes as a function of argon fill pressure. Experimental results indicate that the velocity of current sheet is proportional to $P^{-.46}$ where P is fill gas pressure. The velocity of current sheet follows the snow plow model ($v \approx P^{-0.5}$) as expected. Figure 4 shows the image-converter photograph of the plasma focus discharge at the end-on view. The size of focus is roughly 5mm in diameter and the radial speed is order of 10^6 cm/sec. The typical side-on streak photographs of discharge are shown in figure 5. In the photographs the vertical white line indicates the position of the end electrode. Each vertical black line indicates 5 cm. The time difference between current sheets is about 7μs which agrees with the half-cycle period of the electrical signal. Figure 6 shows the irradiance of the dense plasma focus (DPF) as function of the applied magnetic field. The irradiance of the DPF is about ten times less with the magnetic field

0.8 Gauss than that with no magnetic field, even though shot to shot variation of plasma intensity is less than the case of no magnetic field (normal condition). When 20 Gauss is applied at the end of the electrode, the irradiance of the DPF pumping light turns out to be low, and the variation of plasma intensity is minimal. Thus, the effect of the applied magnetic field to the DPF for stabilization appears to be negative. The physical reason for this effect needs more investigation. Figure 7 shows typical oscilloscope signals of output voltage (top), pumping light (middle) and laser output energy (bottom) from the DPF.

In order to determine the optimum operating conditions of the DPF device for pumping blue-green and near dye laser, the spectral irradiance of the DPF at the dye cuvette was measured as function of the filling gas pressure for argon and deuterium mixture. Figure 8 shows the spectral irradiance as a function of argon fill gas pressure. Figure 9 and 10 show the spectral irradiance of DPF at 355nm as function of the filling gas pressure of argon and deuterium mixture. The peak value of the DPF emission was obtained at pressure of 0.5Torr (10% Ar + 90% D_2). The peak intensity with argon gas in the DPF device was approximately 15 times less than that for the mixture of argon and deuterium. The rise time of the pumping light from the DPF device with argon gas and the mixture of argon and deuterium was the same value of 132ns, respectively. As a result, the total fill gas pressure of 0.5 Torr (10% Ar + 90% D_2) was the best optimum condition for focussing.

Laser output energy of blue-green laser was also measured as a function of argon fill pressure and output laser mirror (Fig. 11), and dye concentration (Fig. 12), were measured. As a result of laser cavity tuning, the maximum untuned laser output exceeded 4mJ. Details of the HCF results are in references in 9 and 10.
The performance of LD490 dye laser is shown as follows :

Laser peak wavelength (untuned)	495 nm
Maximum peak power	4 kW
Maximum pulse energy	4 mJ
Pulse energy density (Max.)	8.3 J/liter
Pulse length (FWHM)	0.5 μs
Angular divergence	5 mrad

III. Hard-core flashlamp for blue-green laser excitation

The hard-core flashlamp (HCF), which is an array of inverse pinches and initiated by the surface discharges, had some advantages that make it a desirable light source for the excitation of blue-green and near uv lasers (Ref. 11). The major advantages are the fast current risetime (less than 0.5μs which was about three times faster than that could be obtained with conventional flashlamp driven by the identical external circuit.) and the feature that the radiation be focussed in a linear cell by an external reflector. This feature is in contrast to the coaxial flashlamp (Ref. 12) and the hypocycloidal pinch (Ref. 13) array in which a laser tube is inserted for close coupling without any focusability.

The experimental setup consists of 1.0μF-40kV capacitor, its charging circuit and a vacuum chamber which houses the HCF as the pump source and a dye cell (Fig. 13). The inner surface of the vacuum chamber is used as a cylindrical mirror for focussing light to the dye cell. The stored energy used to drive the HCF was varied upto 200J. A short (0.2m) transmission line coupled the capacitor *and the HCF via an inverse-pinch switch of a low inductance* (Ref. 14). The measured rise time of the emission in near uv was less than 0.5μs and the use of high pressure (upto 760 Torr) in the chamber prevented the radial motion of the plasma and the increase of the inductance of the HCF. The pulse widths of the emission were within l μs. Figure 14 shows the spectral irradiance of the HCF monitored with an optical multichannel analyzer (EG&G). With low fill gas pressure of argon (0.2 Torr) near uv output is observed stronger than the visible one, while high fill gas pressure of argon (760 Torr) the visible continum is enhanced. It was observed that near uv output of the HCF with alumina insulator core was much higher than that with teflon, and also the radiation output from the HCF increased linearly by a factor of three as argon fill gas pressure increased from 300 Torr to 760 Torr (Fig. 15). These results demonstrate that the source radiance spectrum can be varied with the fill gas type, pressure and material of the core insulator. Figure 16 shows that the pump rate (which is defined to be the ratio of the peak intensity of the radiative output and its risetime) and laser output energy are function of argon fill gas pressure. Figure 15 and 16 indicates that both the pump rate and the corresponding laser

output increase as argon fill gas pressure increases from 200 Torr to 760 Torr as expected. The maximum laser output obtained was 0.9 mJ with peak power of 2 kW. The corresponding energy extraction density is 45J/liter. Details are in Ref. 15.

IV. SUMMARY AND CONCLUSION

A dense plasma focus (DPF) was successfully employed for pumping a dye laser with LD490. The filling gas of 0.5 Torr (10% argon and 90% deuterium mixture) was found to be the optimum. The maximum output energy of the dye laser was 4.0 mJ with 0.5μs halfwidth. The wavelength of the peak laser output was 495nm with 5 mrad of divergence angle. For the case of LD390 dye, the pump power of the DPF was not sufficient to achieve a lasing. For the elliptical mirror used, the optical coupling efficiency was only 20%. The solid angle between the surface of the reflector and the source was approximately $\theta = 37^0$, which corresponds to 10% of the whole radiation. The threshold energy required for the LD390 will be reached by either improving the coupling efficiency of reflector or increasing the input energy to the DPF device or both.

The concept of a new light source, hard core flashlamp, was investigated with a prototype, and its advantages over the other sources have been verified. The emission spectra of the HCF show that spectral modifications for the pump bands of dye laser media can be made. Laser excitation of LD490 was achieved with high pressure argon gas in HCF, and laser output of 0.9mJ was obtained with the pulse width of 0.5μs. The HCF's line focusability was advantageously utilized for forming the laser pump geometry. However, improvements with an elliptical reflector and use of higher driving energy for HCF are left for the future work.

V. Reference

1. "Optically pumped ultraviolet and infrared lasers driven by exploding metal films and wires". C. R. Jones and K. D. Ware, SPIE, Vol. 380, 160 (l983).
2. "Plasma pump source for lasers", V. B. Rozanov and A. A. Rukhadze, Sov. J. Quantum Electronics. 13, 73 (l983).
3. "Pulse-periodic Iodine photodissociation laser pumped with radiation from magnetoplasma compressions", G. N. Kashikov, V. K. Orlov, A. N. Panin, A. K. Piskunov and V. A. Reznikov, Sov. J. Quantum Electron. 10, 1193 (l983).
4. "Investigation of an iodine laser excited optically by high current plasmadynamic discharge", A. S. Kasmrukov, G. N. Kashinov, N. P. Kozolov, V. A. Malashchenko, V. K. Drlov, and Yu. S. Protasov, Sov. J. Quantum Electron., 6, 1101 (l976).
5. "Ultraviolet laser excitation source", J. H. Lee, D. R. McFarland, and F. Hohl, Applied Optics 19, 3343 (l980).
6. "High power blue-green laser by hypocycloidal-pinch plasma", K. S. Han, S. H. Nam, and J. H. Lee, J. Appl. phys. 55, 4133 (1984).
7. "Performance of an array of plasma pinches as a new optical pumping source for dye lasers", H. Rieger and K. Kim, J. Appl. Phys. 54, , 6199 (l983).
8. "New short-wavelength optical pump consisting of Mather-type dense plasma focus", K. Kim and J. J. Fenning, CLEO'84 Tech. Digest, Paper TUB33.
9. "Dense plasma focus for blue-green laser", K. S. Han, K. D. Song, and J. H. Lee, Bull. APS. 31, 1756 (l986).
10. "A dense plasma pump source for a near uv dye laser" K. D. Song, (M. S. Thesis Hampton Univ.), (l987)
11. "Dense plasma radiation sources for blue-green laser excitation" J. H. Lee, K. S. Han, and D. D. Venable, IEEE 87CH2451-3 Paper 3A6 46 (l987).
12. H. L. Harry etal, IEEE J. Q. E. 7 85 (l977).
13. "UV dye lasers pumped by hypocycloidal pinch plasma" W. J. Yi, D. D. Venable, and J. H. Lee, Proceedings of International Conference on Laser'86 Paper WH5
14. S. H. Choi and J. H. Lee, 22nd Intersociety Energy conversion engineering Conf. (IECEC), Philadelphia, Aug. 10-14, l987, paper 979130.

15. "Hard-core flashlamp for blue-green laser excitation ", K. S. Han, J. K. Lee, and J. H. Lee 3rd Int. Laser Science Conf. Bull. APS. Vol. 32, 1642 (l987).

List of Figures

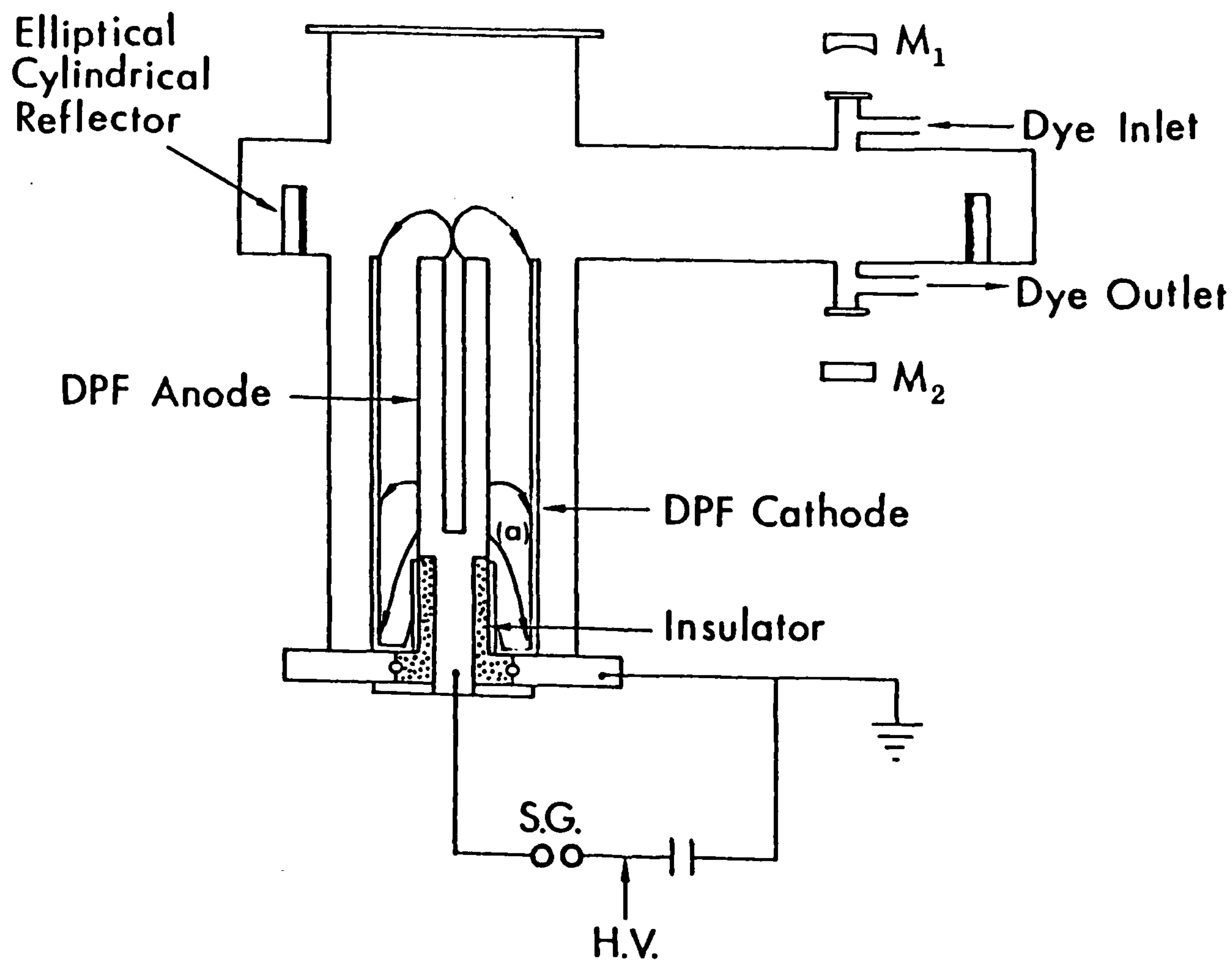


Figure 1. Experimental setup of the dense plasma fo cus and dye laser systems.

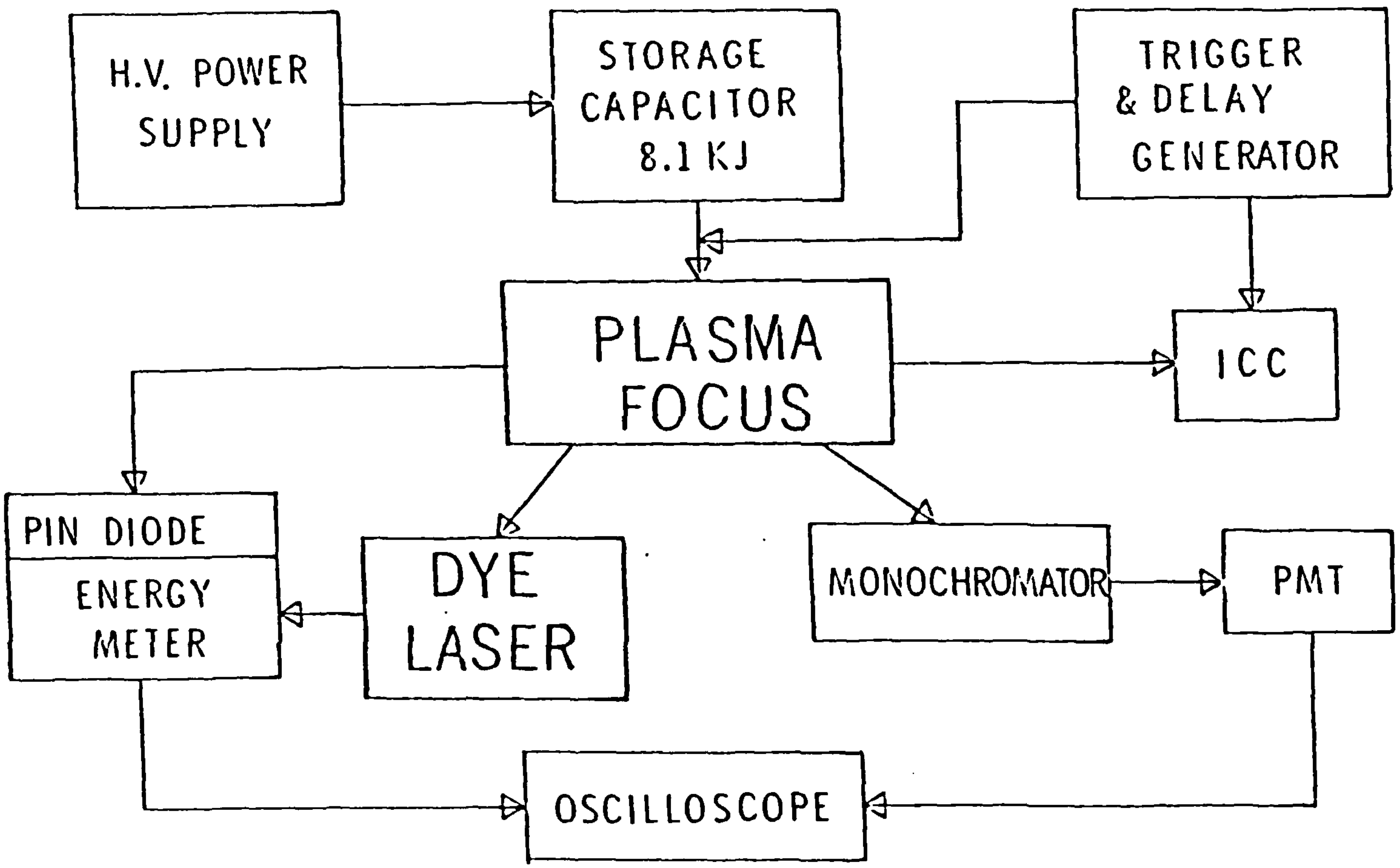


Figure 2. Block diagram of experiment for monitoring laser signal, current sheet and formation of plasma focus.

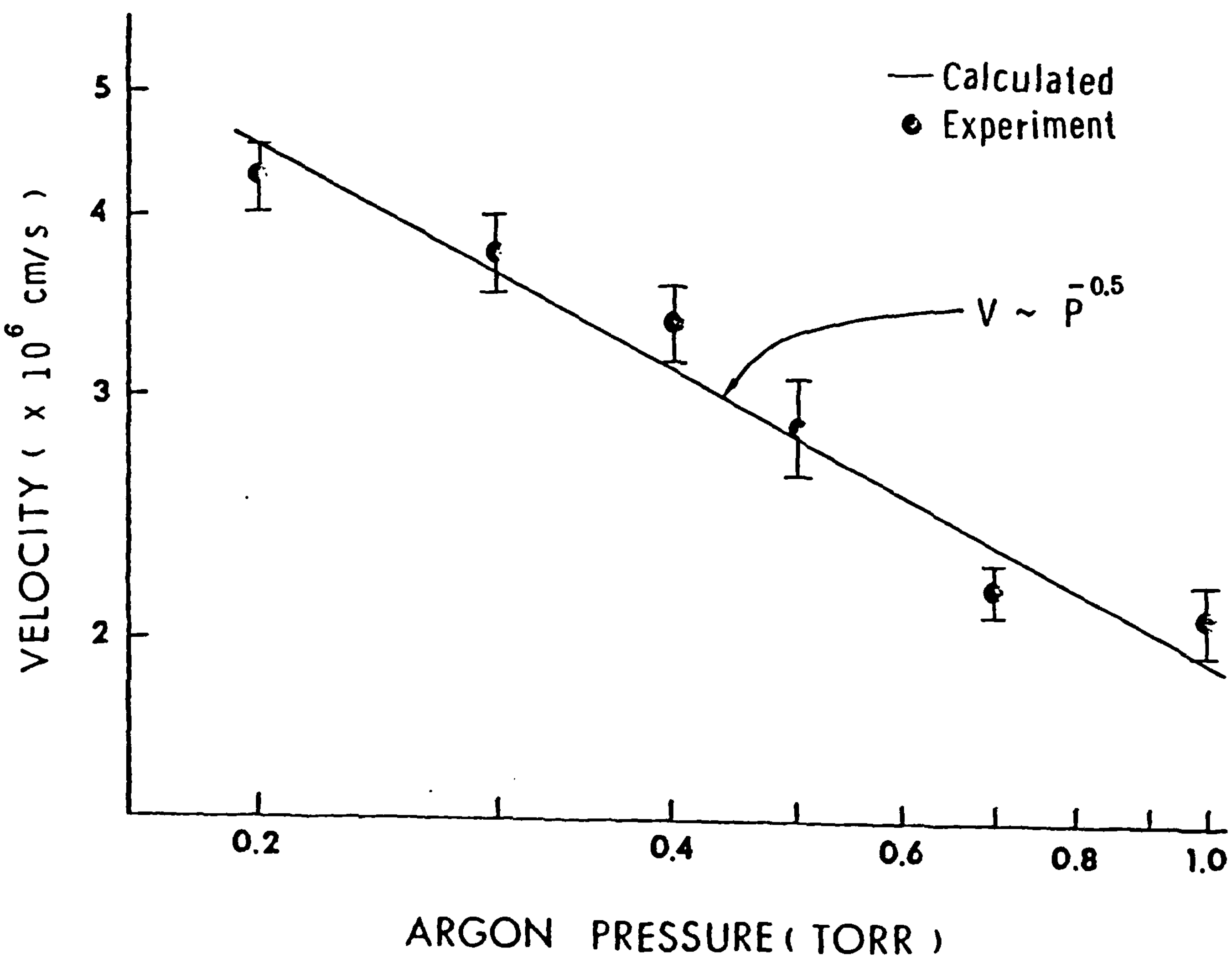


Figure 3. Average speed of current sheet of the plasma pumping source as a function of argon fill gas pressure.

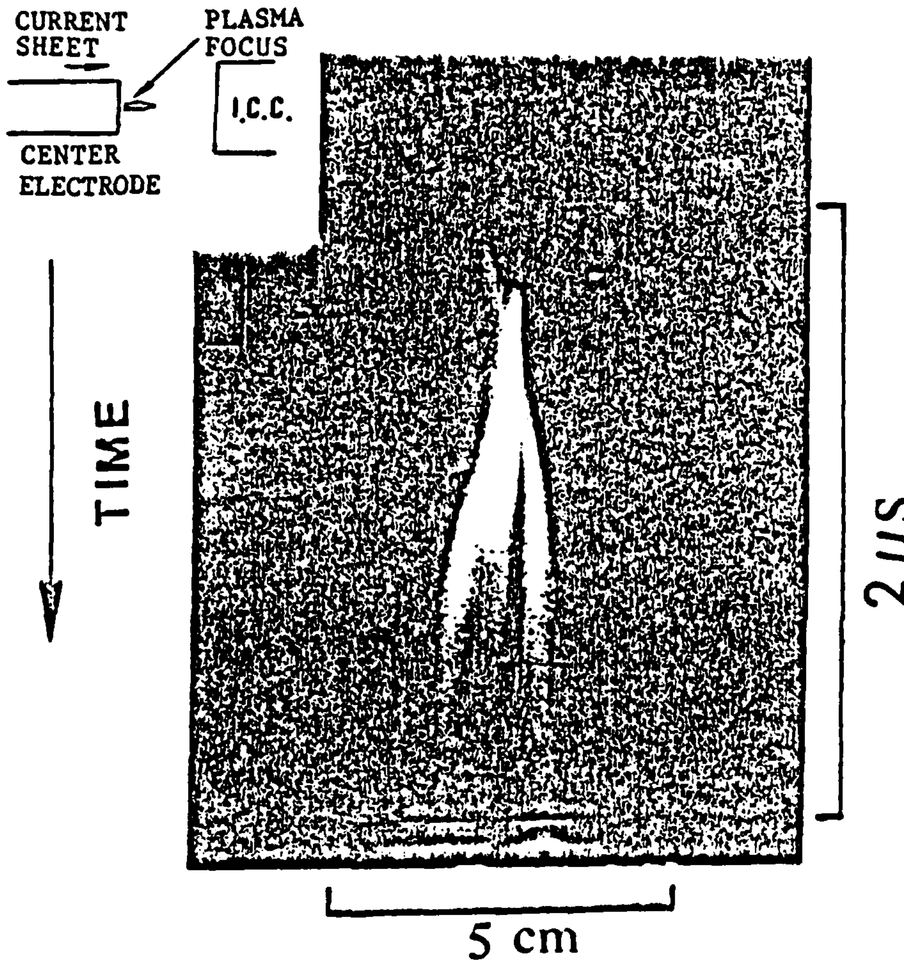


Figure 4. Typical end-on streak photograph of plasma focus discharge. The input energy was 8.1 kL (18 kV) and streak duration 2 μs.

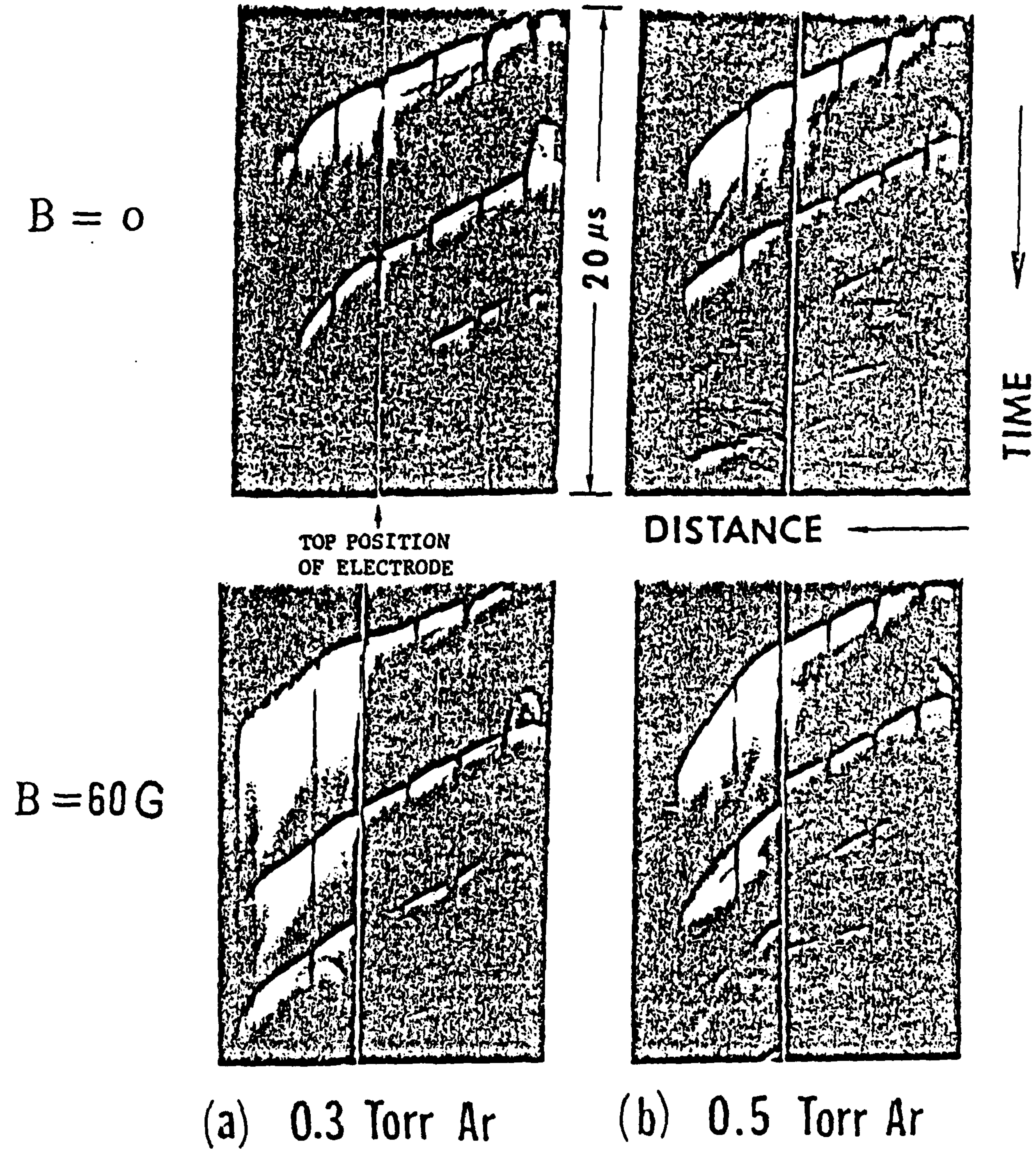


Figure 5. Typical side view of streak photograph of plasma focus discharge. The input energy was 8.1 kJ (18 kV) and streak duration 20 μs.

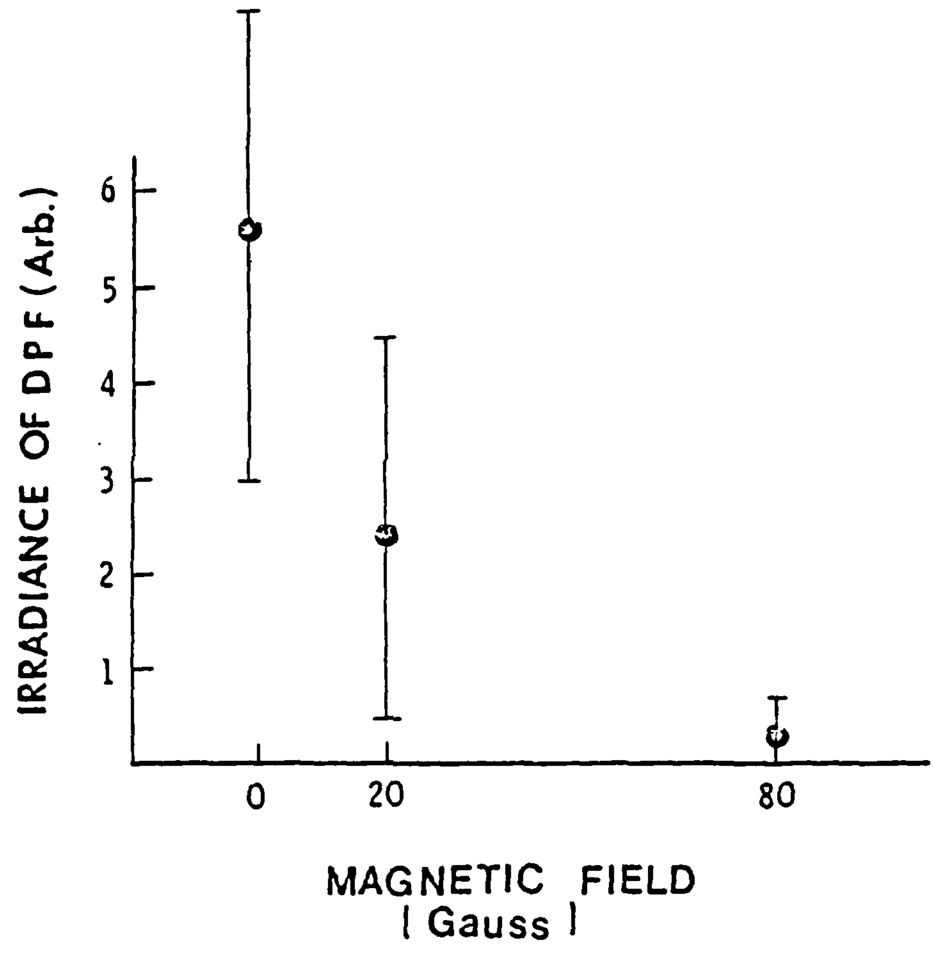


Figure 6. The irradiance of DPF as a function of the stabilizing magnetic field for plasma focus. The input energy was 8.1 kJ, and total fill gas pressure 0.5 Torr (10% agron an 90% deuterium), and the wavelength at 355nm.

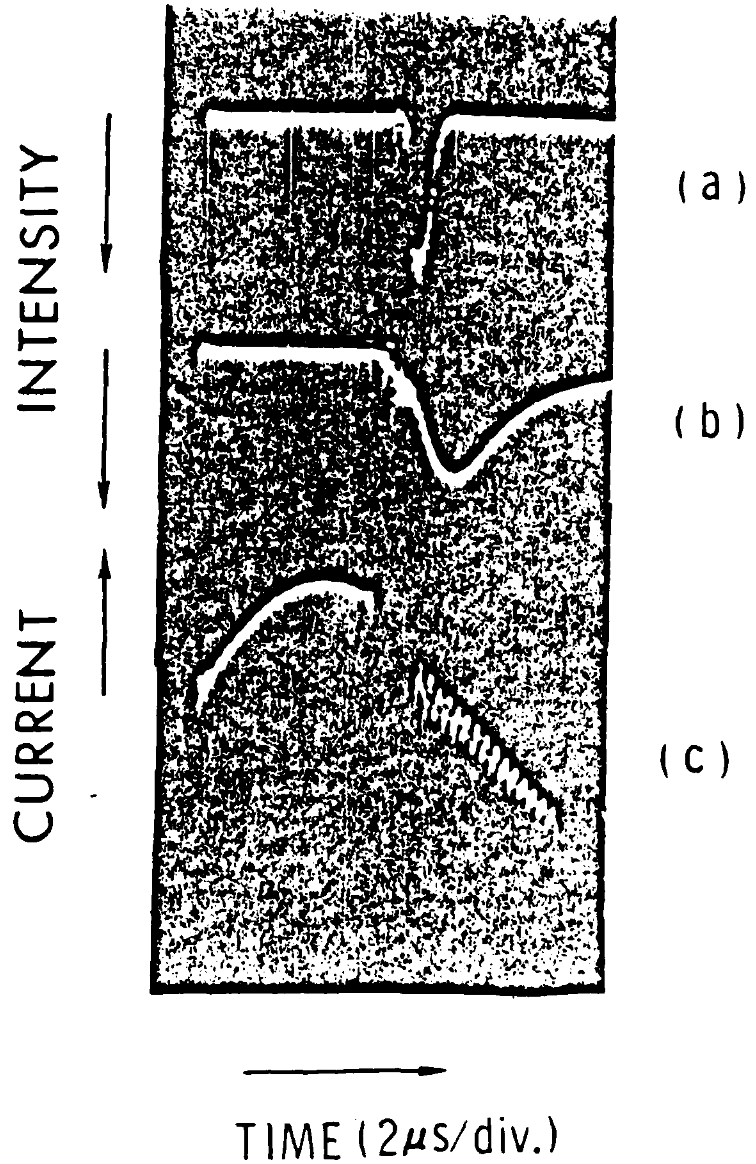


Figure 7. Typical laser (a), pumping light (b), and current (c), for LD490 laser. Sweep speed was 2 μs/div.

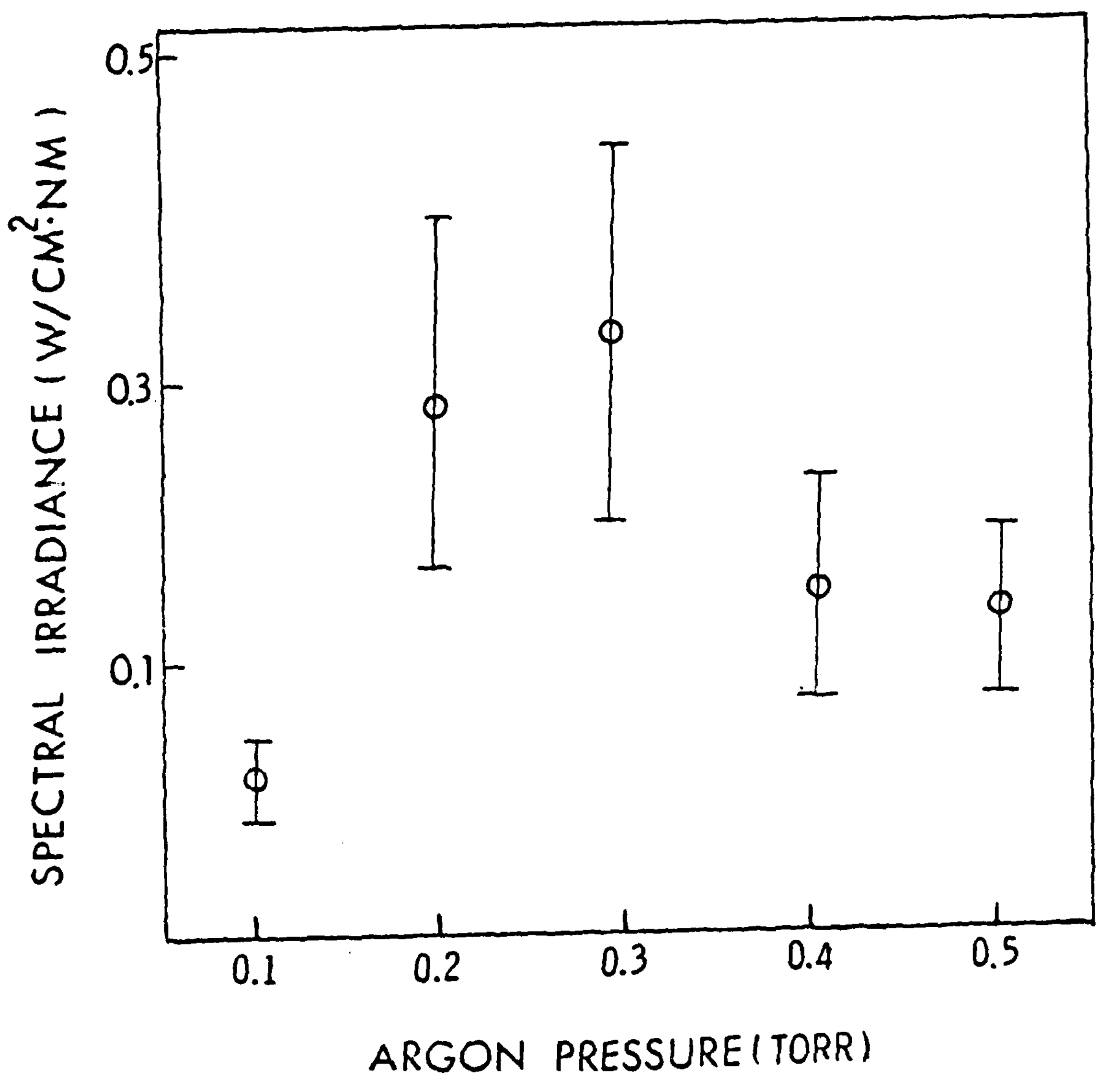


Figure 8. The typical irradiance of DPF as function of argon fill pressure at 355nm. The input energy was 8.1 kJ.

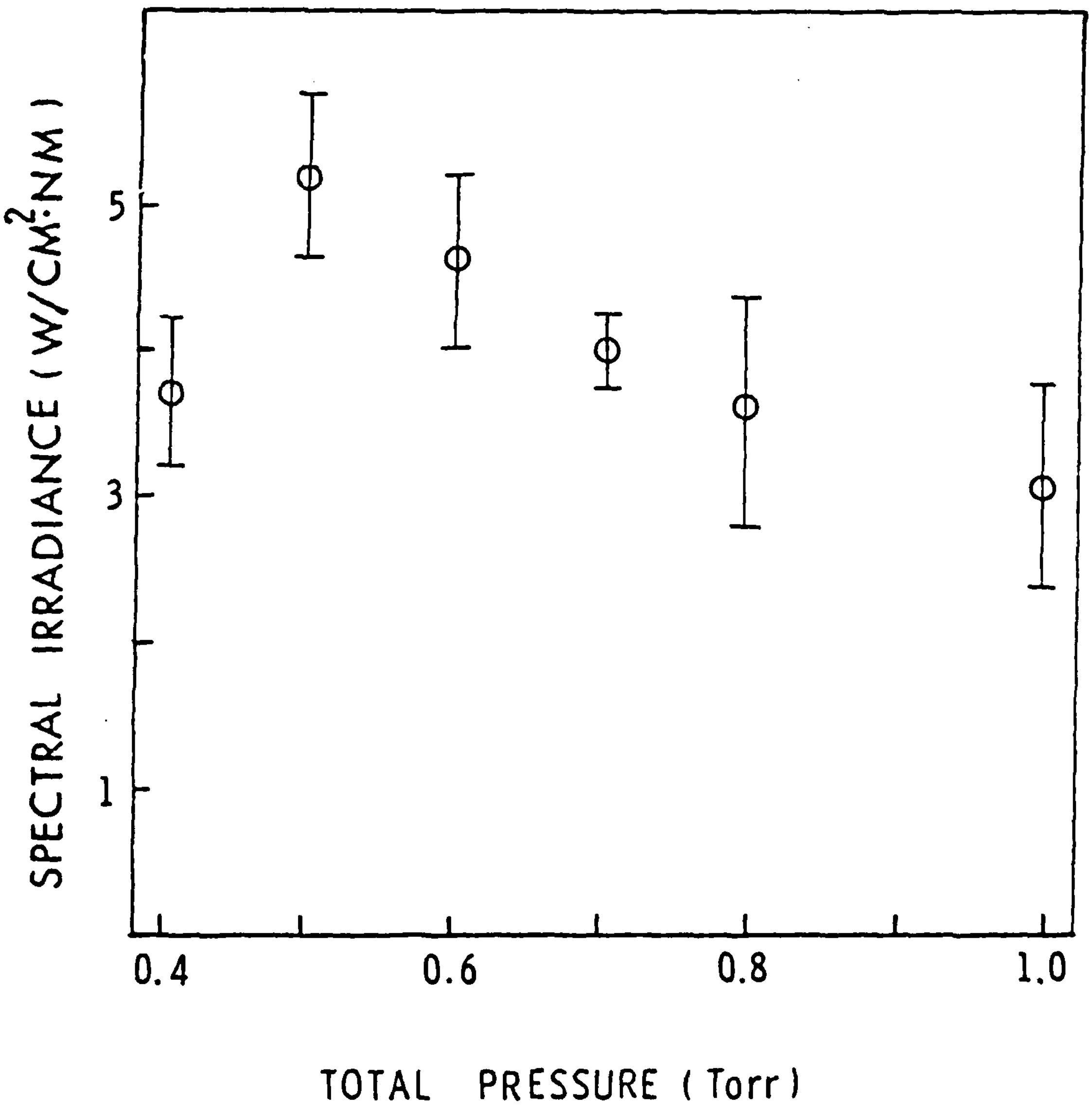


Figure 9. The spectral irradiance of DPF as a function of total pressure (10% Ar+ 90% D_2 mixture). The input energy was 8.1 kJ.

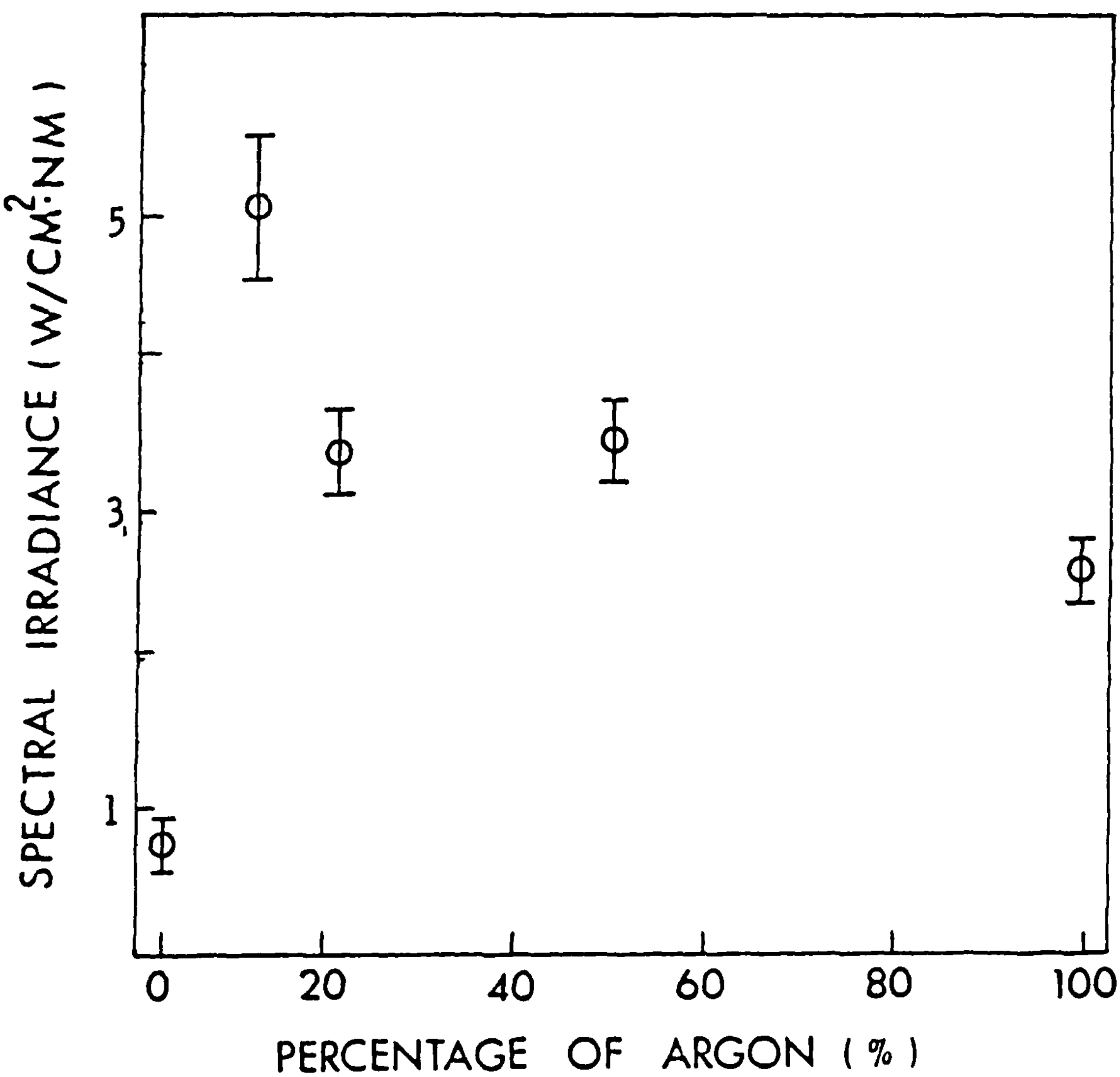


Figure 10. The spectral irradiance of DPF at 355nm as a function of percentage of argon with 0.5 Torr total pressure.

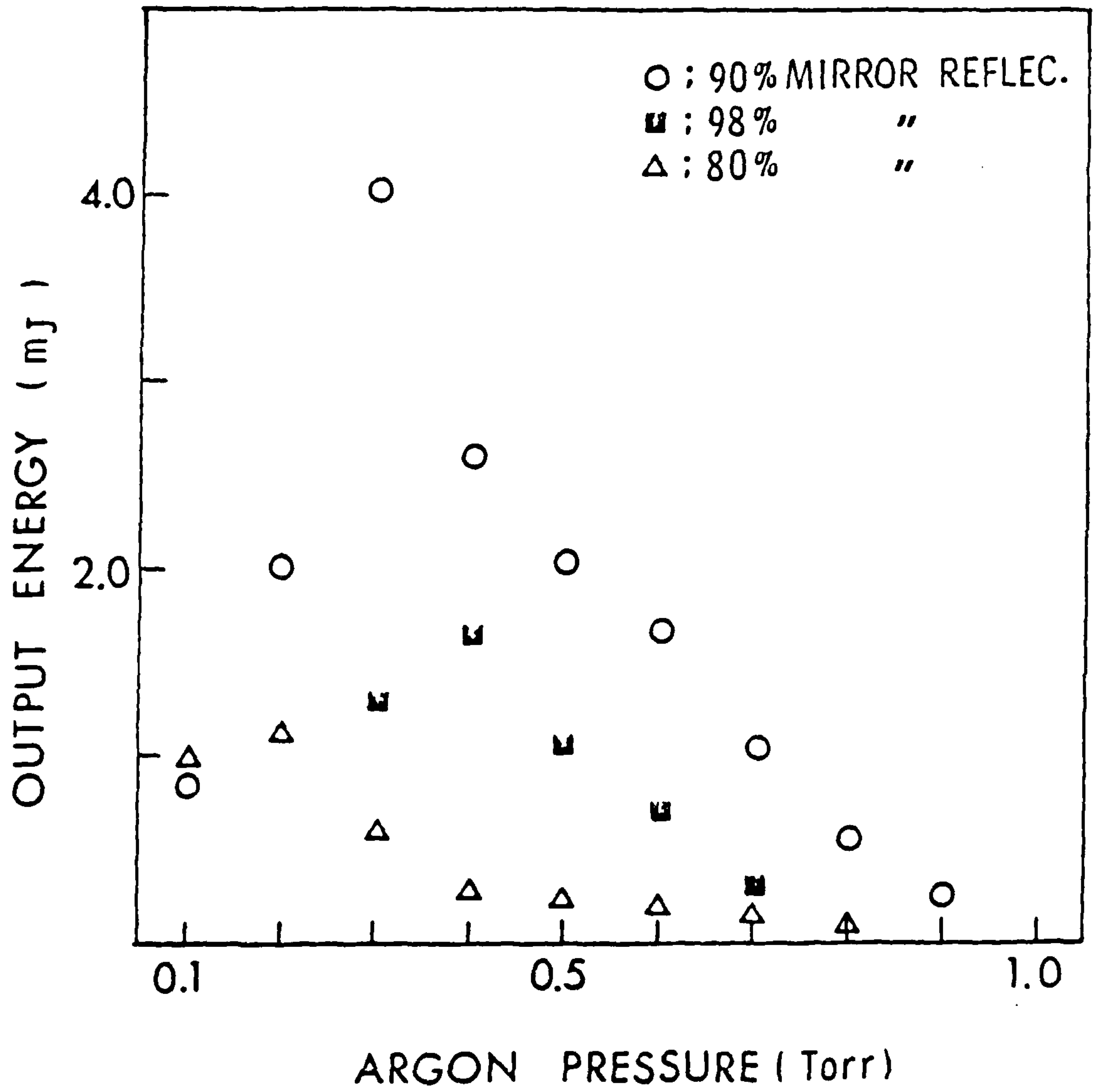


Figure 11. Laser output energy as functions of argon pressure with

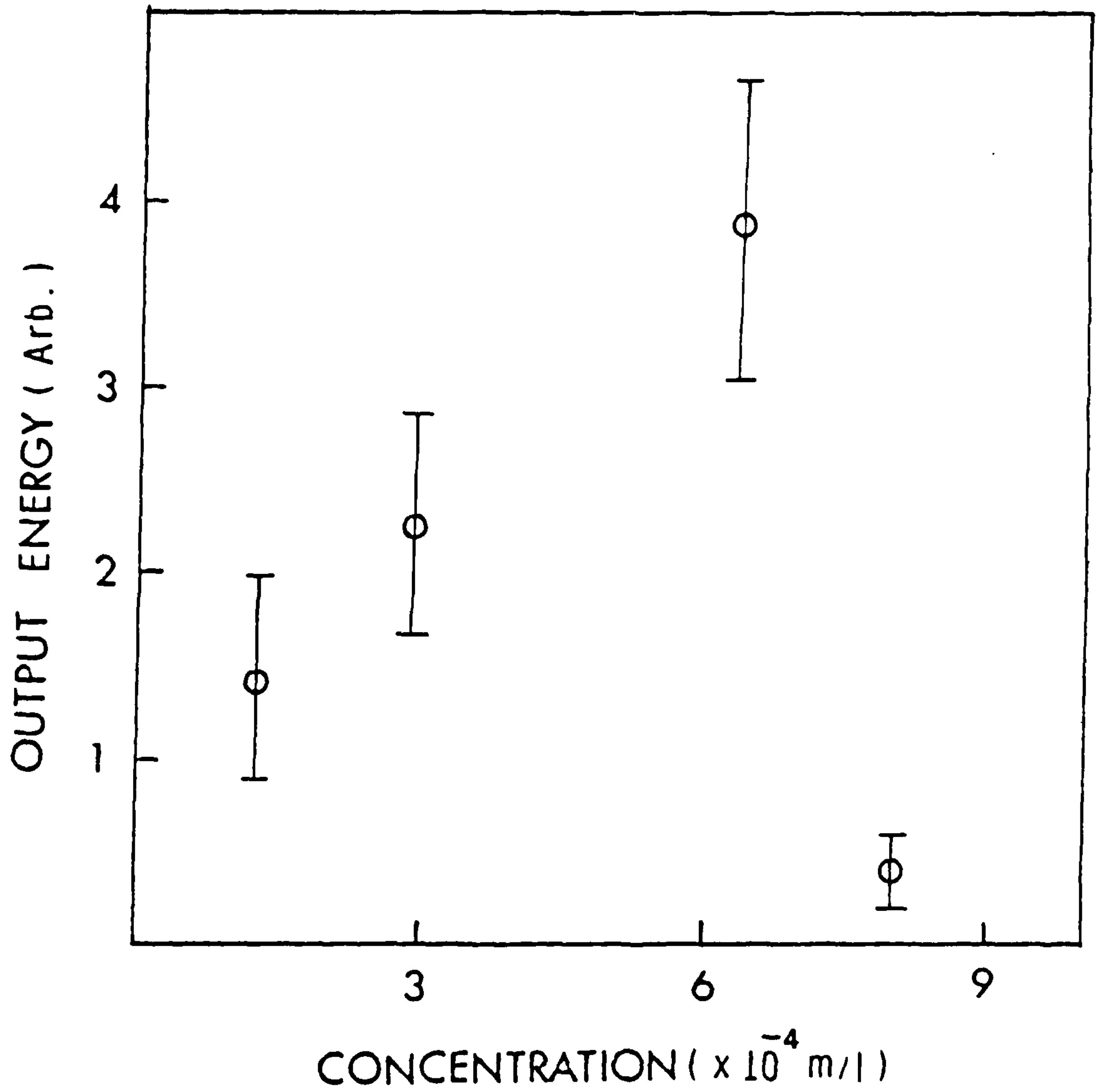


Figure 12. Laser output energy as function of dye concentration of LD490.

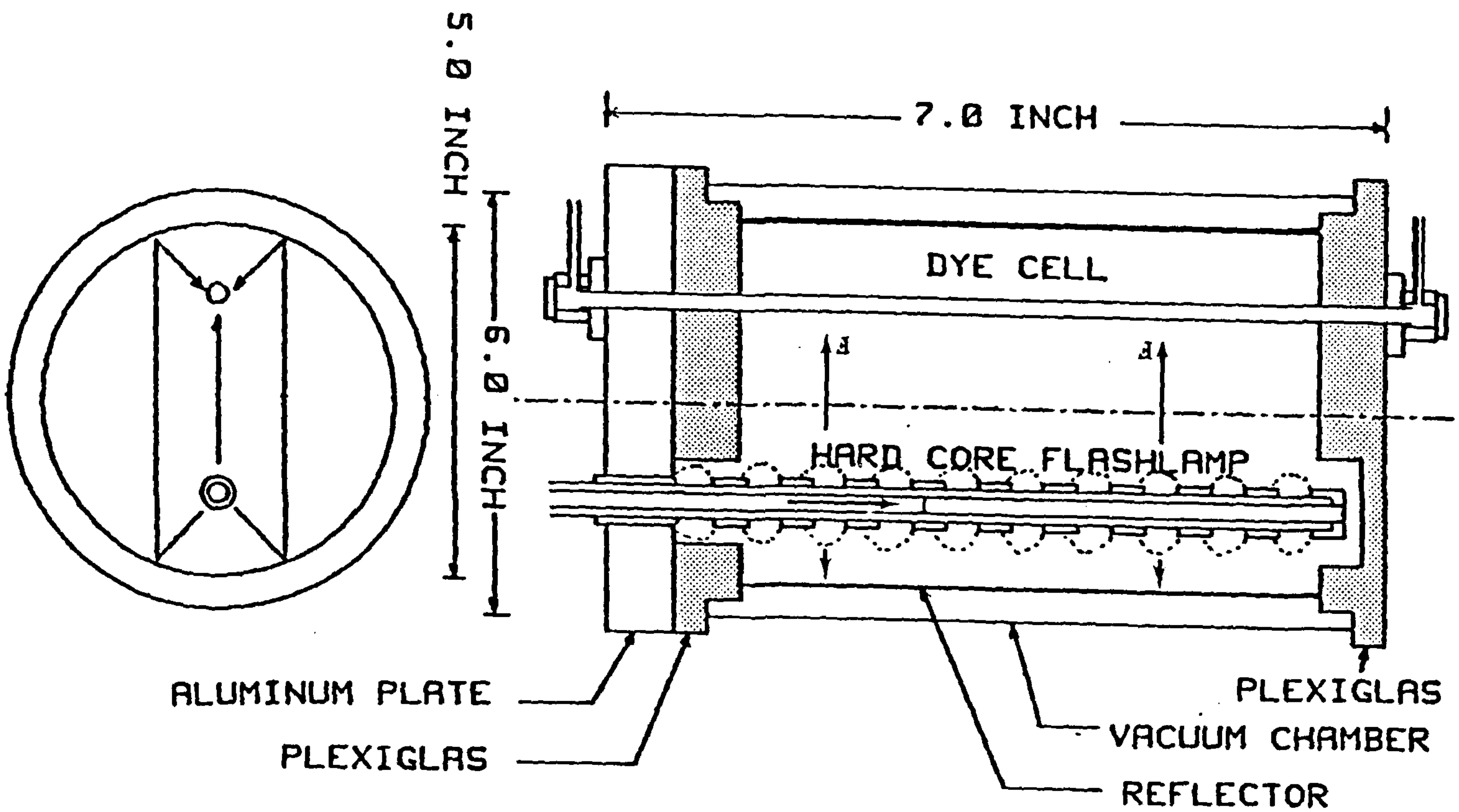


Figure 13. Cross-sectional view of HCF in vacuum chamber. The flashlamp and the dye cell are placed in a hollow cylindrical mirror for focussing light to the dye cell.

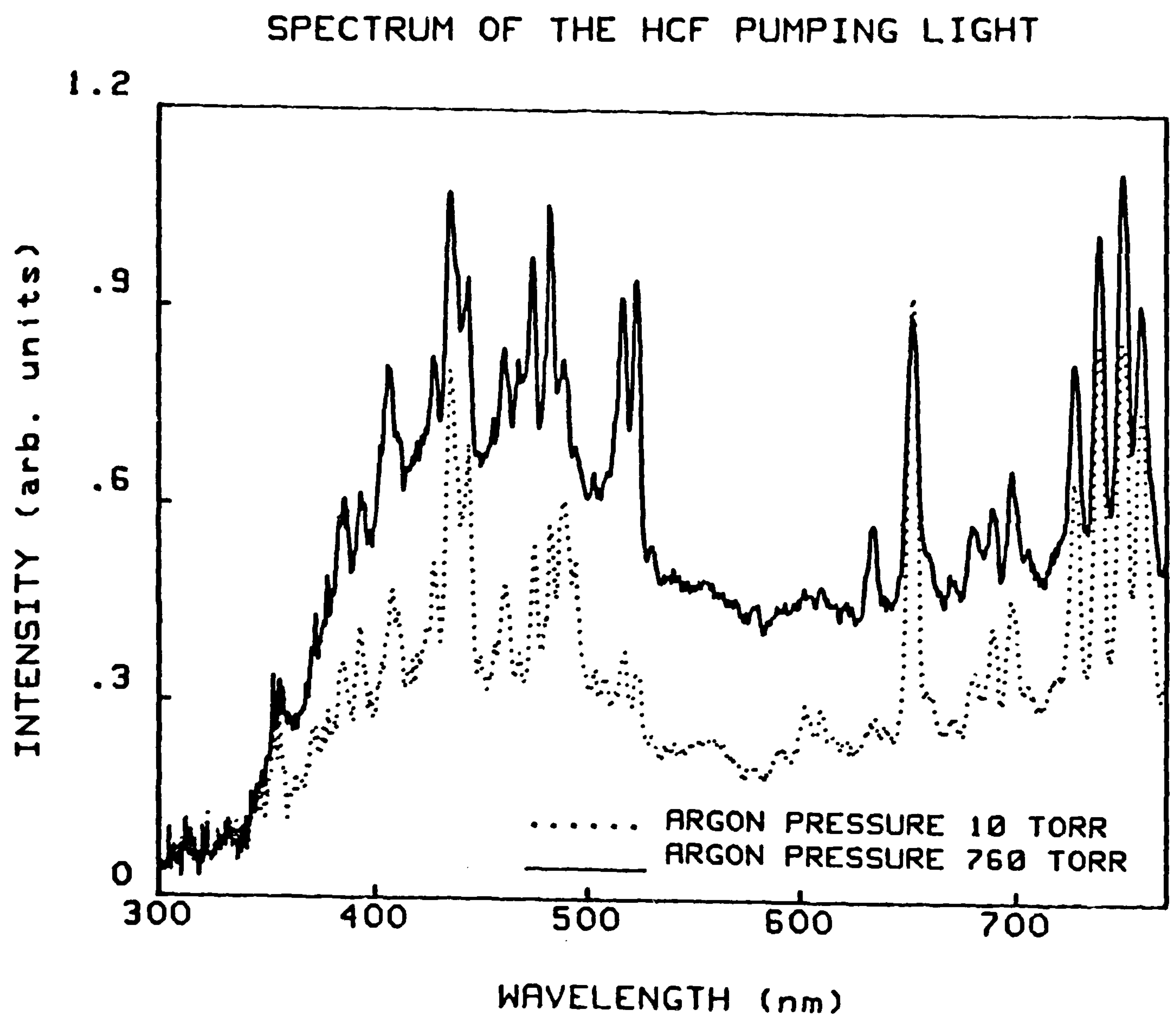


Figure 14. The spectrum of the HCF emission monitored by an optical multichannle analyzer (Eg&G). The electrical input energy to the HCF was 200J.

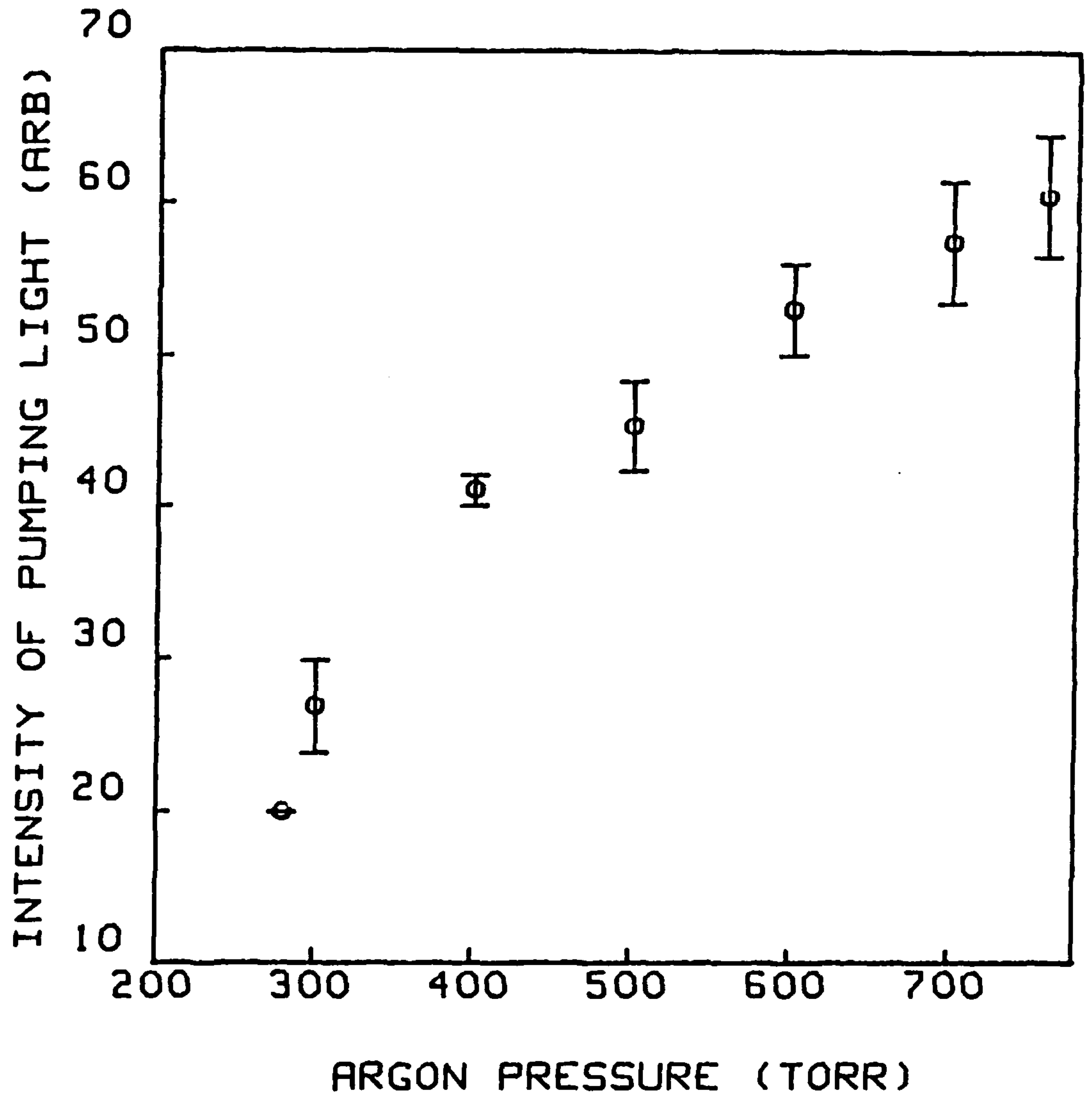


Figure 15. The radiation output of HCF as a function of argon fill gas pressure. The output was monitoed by a PM tube (UVP1200) and an interference filter (400nm).

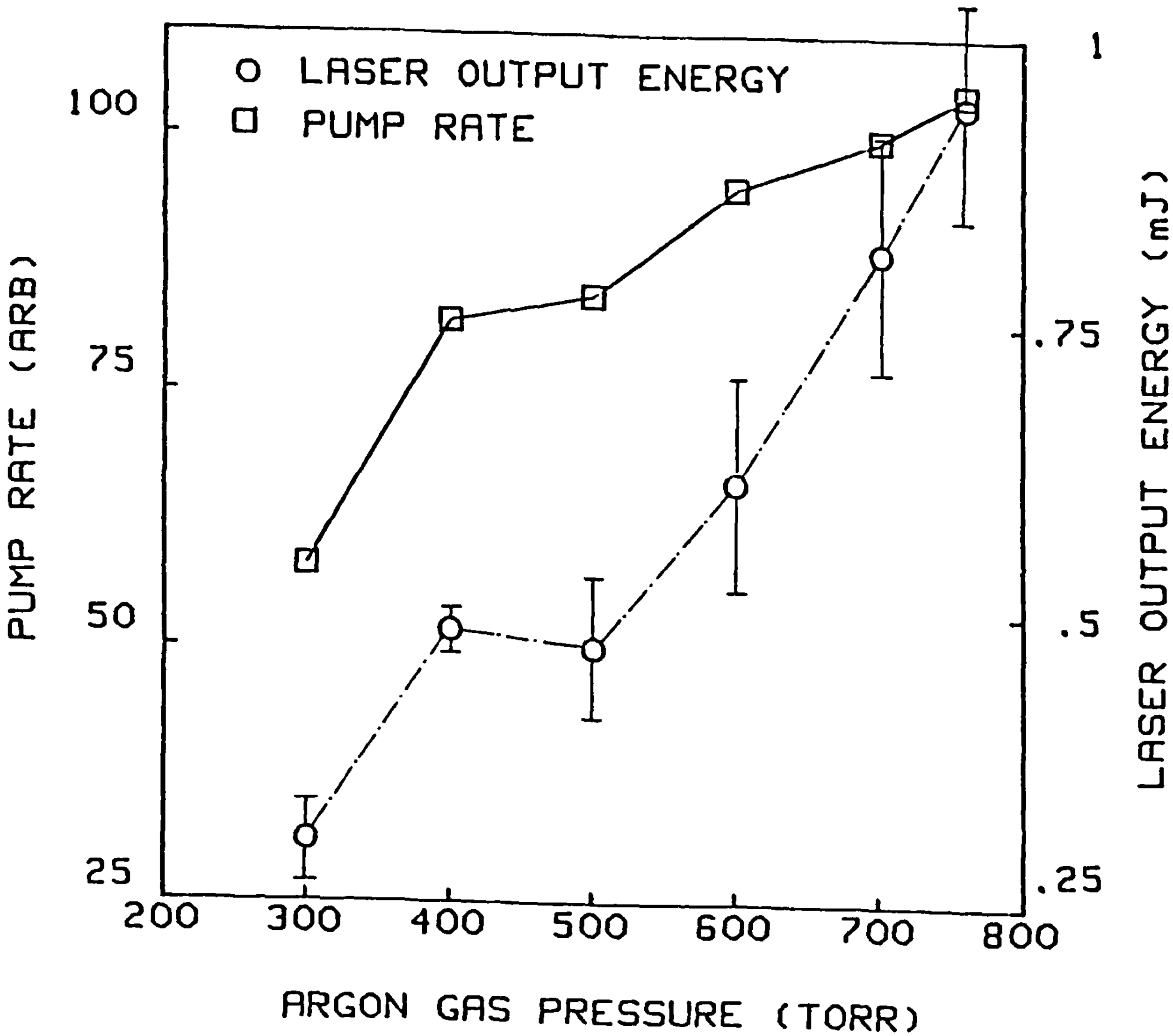


Figure 16. The pump rate and laser output energy of LD490 as a function of argon gas pressure.

VII. List Of all participating Scientific Personnel
under
ARO grant (DAAL03-86-G-0003)
Period Jan 15, 1986 - Feb 28, 1988

Name	Title	Period
K. S. Han	(Principal Investigator)	Jan 15, 1986 - Feb 29, 1988
J. H. Lee	(Faculty Associate and Adjunct Prof. of Physics)	Jan 15, 1986 - Feb 29, 1988
K. D. Song	(Graduate Student)	Jan 15, 1986 - Aug 31, 1986
G. W. Lee	(Graduate Student)	Jan 15, 1986 - Aug 31, 1986
J. K. Lee	(Graduate Student)	Jan 15, 1986 - Aug 31, 1987
Morris Workman	(Graduate Student)	Sept 1,1986 - Dec 31, 1987

VIII. List of Publication
generated
under ARO grant (DAAL03-86-G-0003)
Period Jan 15, 1986 - Feb 29, 1988

1. "Enhancement of Blue-Green Laser Efficiency by a Spectrum Converter" K. S. Han, C. H. Oh and J. H. Lee AIP Conference Proceeding 146. Series 6 181 (1986).
2. "Dye Mixture for Enhancement of Blue-Green Laser Efficiency" K. S. Han, C. H. Oh, J. H. Lee Bull. APS . 31, 833 (1986).
3. "Hypocycloidal Pinch as a Soft X-ray Source for Lithography" K. S. Han, G. W. Lee, and J. H. Lee Bull. APS. 31 1452 (1986).
4. "Dense Plasma Focus for Blue-Green Laser" K. S. Han, K. D. Song, and J. H. Lee Bull. APS. 31, 833 (1986).
5. "A Spectrum Converter Dye for Enhancement of Blue-Green Laser Effciency" K. S. Han , C. H. Oh and J. H. Lee. Applied Physics 60, 3416 (1986).
6. "Dense Plasma Radiation Source for Blue-Green Laser Excitation" J. H. Lee, K. S. Han, and D. D. Venable IEEE 46. 2452-3 (1987).
7. "A Dense Plasma Pump Source for a Near Ultraviolet Dye Laser" K. D. Song (M. S. Thesis, Hampton University), (1987).
8. "Dense Plasma Source for Soft X-ray Lithography" G. W. Lee (M. S. Thesis, Hampton University), (1987).
9. "Hard-Core Flashlamp for Blue-Green Laser Excitation" K. S. Han, J. K. Lee, and J. H. Lee, 3rd International Laser Science Conference, Bull. APS. Vol. 32 1642 (1987).

END
DATE
FILMED
DTIC
6-88